Implications of aging in young supernovae

Poonam Chandra & Alak Ray

Tata Institute of Fundamental Research, Mumbai -400 005

Abstract. We present here the combined radio spectrum from the Giant Metrewave Radio Telescope (GMRT) and Very Large Array (VLA) of type-IIb SN 1993J (age 11 years) and a type-Ic SN 2003bg (age 1 year). In SN 1993J, we find a break in the spectrum at 4 GHz and associate it with Synchrotron cooling break. Hence, we determine the magnetic field independent of equipartition assumption between relativistic electrons and magnetic energy. We also see a hint of break in the spectrum of SN 2003bg between 22-40 GHz. The spectrum of SN 2003bg is well described by the synchrotron self absorption model.

1. Introduction

Synchrotron aging can provide wealth of information related to plasma conditions in young supernovae. We discuss two supernovae in this context - an eleven years old type-IIb supernova SN 1993J and a one year old type-Ic SN 2003bg.

2. SN 1993J in M81

We observed SN 1993J around day 3200 with the GMRT in 610, 235 and 1420 MHz bands combined this dataset with the high frequency VLA observations provided by C. Stockdale & collaboration (see Chandra et al. (2004)). The spectrum suggests a break in the spectral index ($\Delta\alpha = 0.6$) in the optically thin part of the spectrum at 4 GHz (Fig. 1). This variation is consistent with that predicted from the synchrotron cooling effect with continuous injection (Kardashev 1962). Including the effect of acceleration and adiabatic loss processes, and using size of the SN $R = 2.65 \times 10^{17}$ cm on day 3200 from VLBI (Bartel et al. 2002), we obtain magnetic field $B = 0.33 \pm 0.01$ G (Chandra et al. 2004). From the best fit in SSA, the magnetic field under equipartition assumption is $B_{eq} = 38 \pm 17$ mG. Comparison of the two magnetic field determines the the ratio of relativistic energy of particles to magnetic field energy, which is $(0.85 - 40) \times 10^{-5}$.

3. SN 2003bg in MCG -05-10-015

SN 2003bg is type Ic supernova in MCG -05-10-015 (19 Mpc). It was discovered on 2003 Feb 25, most likely two weeks after the explosion. We observed SN 2003bg with GMRT in 1280, 610 and 325 MHz bands between 2003 Feb 2- Feb 8 and it was observed at high VLA frequencies on 2003 Feb 8 by A. Soderberg and S. Kulkarni, thus obtaining the radio spectrum covering $0.3 - 44.0$ GHz. We fit homogeneous Free-free absorption (FFA) and Synchrotron Self Absorption

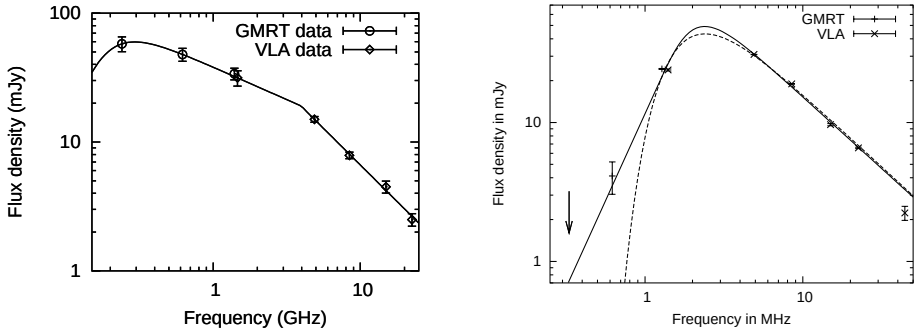

Figure 1. Left Panel: Combined GMRT and VLA spectrum of SN 1993J (day 3200). Solid line shows the SSA fit to the data with the break in the spectrum ($\Delta\alpha = 0.6$) at 4 GHz. Right panel: SSA (solid line) and FFA (dashed line) fits to the combined GMRT and VLA spectrum of SN 2003bg.

(SSA) models to the spectrum (see Fig. 1). The 610 MHz data point clearly eliminates the FFA model and favors the SSA model. We find the following parameters from our fits: spectral index ($\alpha = 3$), size of SN 2003bg ($R = (9.98 \pm 0.43) \times 10^{16}$ cm), expansion speed ($v = 33,000\,\mathrm{km\,s^{-1}}$), and magnetic field ($B = 0.18 \pm 0.03$ G). There seems to be hint of a break around 30 GHz, although this could be due to calibration problems at high frequencies. We need the radio spectrum extended beyond 40 GHz to determine if the break is real. We are planning simultaneous observations of SN 2003bg with GMRT along with VLA and ATCA. This will provide us the spectrum from 0.2 GHz to 80 GHz and will establish whether the spectral break is real or due to data artefact.

4. Discussion and conclusion

The relativistic particle energy density is far below than the magnetic energy density (by a factor of 1/10000). This is quite unlike the expectation of efficient shock acceleration of relativistic particles in SNe. The expected fraction of post-shock pressure in relativistic particles is $W \geq 0.1$ as 10% of the energy ejected by the SNe is needed to power the cosmic rays in the galaxy (McKee 1987). It indicates that perhaps the efficiency of acceleration is either highly variable in SNe, or it will evolve with time in SN 1993J.

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